

*J. Thomson.*

*With kind regards from the Author.*

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ON THE

## WHITE, OR OPAQUE SERUM OF THE BLOOD.

BY

ANDREW BUCHANAN, M.D.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF GLASGOW.

It is well known to all who have been in the habit of examining the characters of the blood, that the serum which separates from it, instead of being transparent and of a yellow colour as we usually find it, is sometimes opaque and turbid, white as if milk had been diffused through it, or otherwise discoloured. Such serum is usually spoken of as white or milky serum. My present intention is to submit to the Society a few observations as to the causes in which this remarkable appearance of the serum of the blood originates.

It has been affirmed, that the blood itself is sometimes of a milky colour as it issues from the veins, or exhibits white streaks diffused through its dark-red substance. That this latter appearance is sometimes observable within the blood-vessels of live animals, more especially in the vicinity of the heart, and that it is occasioned by the chyle mingling but not yet incorporated with the blood, we have the testimony of various physiologists, as of Pecquet, who by tracing the white fluid to its origin, was led to the discovery of the two great trunks by which the lymphatic vessels communicate with the blood-vessels. In human blood flowing from the veins, I have never seen either white streaks or diffuse whiteness. I have indeed heard of such appearances being observed, but I am satisfied that they must be of very rare occurrence from my having looked for them so often in vain in the circumstances in which, as is shown below, they were most likely to have presented themselves. It appears to me, therefore, probable, that the indofinite expressions "white" or "milky blood," employed by Haller, and by many other writers before and since, must refer chiefly to the white state of the serum. This is certainly the meaning of some of the authors quoted by Haller, as

of Tulpius, who conceived the white matter in the serum to be absorbed milk, and warns his patient against that beverage in time to come. Haller himself, however, takes no notice of this colour of the serum, and many of his expressions obviously imply a belief that the whiteness was an attribute of the whole mass of blood.\* The only appearance, so far as I have ever seen, which could justify the application of such epithets to the blood, is that observed in inflammatory blood, which, when just about to coagulate, becomes whitish or bluish upon the surface. But this affords no solution of the difficulty as to the words of Haller, who expressly states that he omits all consideration of such blood.† We are therefore unwillingly compelled to recollect, that the same great physiologist, after a laborious examination of the arguments on both sides, declares that there is little or no difference in appearance between arterial and venous blood; and to conclude that the observations then made as to the colour of the blood were not worthy of implicit reliance.

Hewson introduced a more accurate mode of speaking of these phenomena, by referring the whiteness to the serum, and not to the general mass of blood. Hewson, also, first minutely described this condition of the serum, and analysed the circumstances on which it appeared to him to depend. He rejects the opinion, which was prevalent previous to his time, that the white colour was owing to unassimilated chyle circulating in the blood vessels. He ascribes it, on the contrary, to fat absorbed from the adipose tissue, which he supposes to be taken up more rapidly than the wants of the system require, and, therefore, to accumulate in the blood vessels. He further regards the phenomenon as generally connected with a state of disease; as with plethora, or a stoppage of natural evacuations. Such has been the authority of the name of Hewson, that both these opinions have been taught in the schools of physic ever since his time, and are generally received by the most eminent physicians of the present day. John Hunter stands almost alone in rejecting Hewson's doctrine, that the whiteness of the serum is owing to absorbed fat, "which," he says, "is certainly not the case; for it is not the same in all cases:" by which I understand him to mean, that the characters of white serum are not sufficiently uniform to warrant the supposition, that the colour is always occasioned by the same substance. Hunter also rejects the opinion that the white colour is due to unassimilated chyle; "because, it does not occur frequently enough" to be ascribed to that cause. He observed it most "frequently in the blood of breeding women," and therefore conceived it might have some connection with the pregnant state; but, as he observed it also in other females and in men, he

\* *Nempe in vivis animalibus, chylum albo suo colore conspicuum, sæpe per vasa sanguinea oberrare, de vulnere fluere, aut in cor ipsum apertum de auricula effundi vidi.* Tom. ii. p. 14, *Element. Phys.*

† *Id. ibid.*

seems to have been at a loss what to think of it, "for," says he, "so far as I have been able to observe, it can hardly be said to have any leading cause."\* Professor Trail of Edinburgh, has given an excellent account of three cases of a "cream-yellow" state of the serum, apparently connected with inflammation of the kidneys or liver, and he proved the existence in this serum of a fixed oil, as Hewson had done before him. Dr. Trail also first directed attention to a kind of serum like water gruel, in which he could discover no oil. He rejects the idea of the whiteness of the serum proceeding from the food, for that, he says, would have been long since detected. He embraces Hewson's opinion, that it is a pathological phenomenon, and caused by the fat being absorbed "by a diseased action of the vessels."† Dr. Christison seems to regard "lactescent serum" as a symptom of incipient granular disease of the kidneys. Some eminent modern physicians look upon it as a part of the series of morbid changes in the fluids of the body which occur in diabetes. Dr. Williams, in his recently published "*Principles of Medicine*," enumerates milky serum among the diseases of the blood. He thinks it most probably occasioned by an increased absorption of fat, occurring during any rapid diminution of the bulk of the body. Last of all, to conclude this sketch of the prevailing opinions upon this subject, M. Lecanu, who is generally looked upon as the highest continental authority as to the constitution of the blood, enumerates various diseases, of which "milky blood" is an accompaniment; he ascribes it, like his predecessors, to an increase of the fatty matter, while he gives as an additional cause, a disappearance of the red globules of the blood.

My attention was particularly directed to this appearance of the serum in the year 1840, owing to the frequency with which it presented itself during some experiments I was then engaged in making on the constitution of the blood. I observed with Hunter, that it was of very common occurrence in the blood of young women, who desired to be bled, either because they were, or supposed themselves to be pregnant; and whom, if no circumstances forbade, it was the custom to gratify in their request. Now, as these young women were for the most part strong and lusty, and therefore likely to take their food well, I was in doubt whether to ascribe the whiteness of the serum to their peculiar state of body, or to the food which they had probably taken not long before. To resolve these doubts, the most direct mode was to have a person in sound health bled at different periods after a full meal, so as to observe the effects of digestion upon the blood. Accordingly, a strong healthy young man, to whom a good dinner was an equivalent for the loss of a few ounces of blood, was easily prevailed upon to submit to the following regimen and treatment. He had no breakfast, and at four o'clock had for dinner one pound of beef-steak, half-a-pound of bread, sixteen liquid ounces of brown soup, and half-a-bottle of portor. Three ounces

\* On the Blood, 37—39.

† Edinb. Med. and Surg. Journal, 1821 and 1823.



of blood were then taken from a vein in the arm at three different periods ; the first time, half-an-hour after the meal ; the second time, an hour and forty minutes after it ; and the last time, next morning at eight o'clock, or sixteen hours after the meal, no food having been taken in the interval. The blood as it issued from the vein had the usual appearance, and the serum which separated from it was about the same in quantity each time. The first time the serum was whitish and turbid ; the second time it was like whey ; while the third time it was perfectly limpid. The crassamentum on the two first occasions exhibited nothing peculiar, while on the last it was covered with a transparent fibrinous crust beautifully interspersed with white dots ; which led the medical friend, who assisted me in these investigations, to compare it to a precious stone.

As it might be supposed that this young man's blood was white before he took dinner, the two following trials were made to obviate that objection.

A vigorous man of about 35 years of age, after fasting 19 hours, had for dinner, twenty ounces of beef-steak, sixteen liquid ounces of brown soup, and eight ounces of bread. He was bled immediately before his meal, and three times after it, two ounces of blood being taken away each time. The serum obtained from the first bleeding before the meal was perfectly limpid ; the serum from the second bleeding, three hours and fifteen minutes after the meal, was turbid ; the serum from the third bleeding, eight hours and fifteen minutes after the meal, was still thicker ; while that from the last bleeding eighteen hours after the meal, was again quite limpid, although some supper had been eaten in the interval.

The young man first mentioned, after fasting eighteen hours, dined upon sixteen ounces of brown soup, four ounces of bread, eight ounces of potatoes, twenty ounces of beef-steak, and sixteen ounces of London porter, and fasted eighteen hours after the meal. He had blood taken from his arm four times to the extent of two ounces each time. The serum of the blood first taken, immediately before the meal, was of an amber yellow and quite transparent ; the serum from the second bleeding, two hours and ten minutes after the meal, was turbid ; the serum from the third bleeding, eight hours after the meal, was exactly of the colour of water gruel and quite opaque ; the serum of the blood last taken, eighteen hours after the meal, was still turbid, its limpidity not having been, as after his usual fare, restored by an eighteen-hours' fast.

In neither of the two last cases did the blood, as it issued from the arm, present white streaks or any thing else unusual. The crassamentum of the blood drawn before the meal, was in both cases of the usual red colour on the surface, as also that drawn first after the meal in the last case ; but in all the other instances it exhibited the same *pellucid fibrinous crust* already described, although not dotted in the

same remarkable way. We can scarcely avoid the conclusion that this pellucid crust is connected with finished digestion, when we reflect that out of nine bleedings practised within eighteen hours after a very full meal, this crust was observed on every occasion, if we except those in which the blood was drawn within three hours and a quarter of the period of taking the meal.

These observations, the accuracy of which I have since had opportunities of confirming, appear to me to leave no doubt as to the origin of the white colour of the serum of the blood. When a healthy man is bled fasting, his blood yields serum of a transparent yellow colour, like light Sherry wine, varying in the depth of the yellow tint, but always perfectly clear. In about half-an-hour after taking food, the serum becomes turbid, the discolouration increases during several hours till it attains its maximum, after which the serum becomes again gradually clearer, till its limpidity is perfectly restored. The period at which the discolouration is greatest, and the length of time during which it continues, must depend mainly on the quantity of food taken, but also in some degree on its quality, as some kinds of food are digested more readily than others. It may however be stated, so far as the observations I have made enable me to judge, that after a full meal of different kinds of food, the discolouration is greatest about six or eight hours after the repast, and that probably somewhat more than an equal period elapses before the serum regains its limpidity. The differences of colour, which are considerable, probably depend on the different substances digested: and it is interesting in this point of view to remark, that the colour varies in the successive bleedings after the same meal, as if the different alimentary principles produced different kinds of discolouration, and entered the blood-vessels at different periods.

It may be inferred from the facts narrated above, that the food digested in the stomach and bowels is introduced into the system, and mingled with the blood in a crude or half assimilated state; and that it requires to undergo a second digestion within the blood-vessels before it is perfectly assimilated. It is a highly interesting inquiry by what means this second digestion in the blood-vessels is effected. The analogy of plants would indicate the lungs as being the principal agents, for we find the crude sap brought by the sap-vessels to the leaves or organs of respiration, converted by them into the *succus proprius* or true blood of the plant. The respiratory act in man is not confined to the lungs, but takes place in every part of the system to which the absorbed oxygen is carried by the arterial blood: but it is a confirmation of the view just suggested, that at no time do we feel the want of free air more severely than soon after a full meal. In all probability, however, the process of assimilation in the animal body is more complicated than in plants, and may require the co-operation of various organs.

It is at present a matter of doubt among physiologists whether the



primary nutritious liquid prepared by the digestive organs, is introduced into the blood through the lacteals, or through the branches of the portal vein. It cannot, however, be doubted, that when the nutritious matter is first absorbed, it is in the liquid state. It is remarkable, therefore, that it should be found afterwards in the blood as a precipitate, or in the solid state. It may, however, be readily conceived how this effect will be produced, when we reflect, that the food is dissolved in the stomach by an acid liquid; which, if absorbed by the veins of the stomach, will, on mingling with the blood, be at once rendered alkaline, and will therefore let fall whatever substances its acidity enabled it to dissolve. This reasoning, however, is no longer applicable, if we suppose the white matter of the blood to be derived from the admixture with it, of the alkaline chyle. A different explanation was suggested to me by Dr. R. D. Thomson. He supposed that the white matter of the serum might be soluble in it at blood-heat, just as the urate of ammonia and other sediments which often appear in the urine upon cooling, are held in solution at the natural heat of the body. On trying the effect of artificial heat, we found that the serum became considerably clearer, but it was still opaque.

It may also be supposed, that the serum is capable of dissolving a certain quantity of white matter, but after being saturated, deposits any superfluous portion. In confirmation of this view, I may remark, that the relative quantity of serum and crassamentum has an effect on the tint of the serum. Two individuals who had dined upon gelatin, had each the serum opaline, at the end of the third hour after the meal: after six hours the opaline tint was merely somewhat deeper in the one case, while in the other the serum was as opaque as I ever saw it; but on comparing the quantity of serum obtained from the same measure of blood in these two cases, it was found to be more abundant by one half in the former case than in the latter.

If any additional evidence be required of the origin of the white colour of the serum of the blood, it may be derived from an experiment of Hewson, from which so acute a reasoner could certainly never have drawn any other than the right conclusion, had it been one of his first experiments; but it was not made till his mind was thoroughly blinded by his theory of *re-absorbed fat*, and he in consequence misinterpreted it. Hewson had found that geese had very commonly white serum, though their chyle was always transparent; and he therefore chose to make his experiment on them. "I therefore" says he, "took two of them that were very hungry, and feeding both of them with oats, one I killed four hours after, when I knew a part of the oats were undigested, and upon examining the blood, I found the serum whitish, and full of small globules; on its being suffered to stand a little time, the white part ascended to the surface like cream. The other was killed forty-eight hours after eating, when its stomach was found empty, and the serum of its blood quite transparent, and without any cream rising to

the surface, or any appearance of small globules, when examined by the microscope." The obvious conclusion from this experiment seems to be, that the one goose was killed while the digestion in the blood-vessels was in progress; but the second not till long after it was completed: whence the milkiness of the serum in the former case, and its transparency in the latter. But instead of drawing this inference, Hewson will have it, that "the whiteness of the serum was occasioned by the fat being re-absorbed faster than it was used, (from its place being supplied by the fresh chyle,) and thence was accumulated in the blood vessels, so as to give whiteness to the serum."

If these views be correct, it is clear that a milky state of the serum of the blood is a phenomenon of the healthy body, and cannot in itself be regarded as a symptom of disease. There are, nevertheless, certain circumstances in which this appearance may serve to indicate the existence of disease, as when it continues during a longer period than according to the laws of health it ought to do. A case is mentioned above, in which, after eighteen-hours fasting, the serum of the blood was still loaded with white particles. The only inference that could be drawn from this fact, was, that the individual had taken a more than usually large quantity of food, and that the digestion in the blood-vessels was protracted in proportion. Perhaps it would not be warrantable to deduce any other inference, even were the milkiness to continue for twenty-four or thirty-six hours after a full meal. But when this milkiness continues for several days, although the appetite is gone and no fresh supply of food taken, it then becomes probable that the digestion in the blood-vessels is no longer going on, as in the healthy state; being like all other functions of the body, subject to retardation and derangement from the condition of the organs by which it is performed. Thus Morgagni found the serum white in the blood of two patients labouring under fevers; of which he describes the one as malignant and attended with much danger, and the other as verging to malignity. In the former, the whiteness was observed in blood taken by the three last of four venesections which were required; and in the latter, in blood taken on the third, and again on the fifth day of the disease.\* Hewson states on the authority of a contemporary, that "a publican, of about thirty-five years of age, and corpulent, had been subject to a bleeding at the nose, to the piles, and to such profuse sweats in the night, as to be frequently obliged to change his shirt in the morning before he got out of bed, but that for some time past, his sweats had ceased. That on September the 23d, he was seized with a bleeding at his nose, which had been preceded by a pain in his head for two or three days; that his bleeding continued till he had lost about two pounds of blood, and then stopt; and that the serum of his blood was as white as milk. That at ten o'clock the same night, the hemorrhage returned, and he lost a considerable quantity; nevertheless, it was thought proper to

\* Morg. Epist. 49, Art. 22.



take sixteen ounces of blood from his arm, during which evacuation he fainted, but his bleeding at the nose stopt. That the serum of this last blood was likewise very white. That on the 25th, in the morning, he again complained of a pain in his head, and about ten o'clock his nose began to bleed again; but the serum now appeared no whiter than whey. That he continued to lose blood during most part of the night, so that it was supposed he could not lose less than two or three pounds, the serum all this time being a little whitish, but so little, that the bottom of the vessel in which it stood could now be seen through it. That his bleeding returned repeatedly, till the third of October, when it entirely stopt, the serum having become more transparent towards the last."

Now, as it can scarcely be supposed that this man had gorged himself with food to such an extent before his illness, that his blood continued white for ten days afterwards, and as a spare diet would certainly be enjoined for so severe a complaint, we must conclude that the process of digestion in the blood-vessels was, in this case, preternaturally retarded, or in a state of disease. I have no doubt that hereafter, when the normal changes produced by digestion upon the blood are better understood, light may be thrown upon the nature of some diseases of nutrition, by administering certain articles of food, and examining the condition of the blood so many hours afterwards.

It is a fact of great interest, which has been established by various observers, that in diabetes, the serum of the blood often presents the milky opacity in great intensity. This is no more than might have been anticipated from the very large quantity of food taken by those labouring under that disease, which is often three or four times greater than is consumed by persons in health: for if the stomach act upon the food in the usual way, it cannot but happen that the blood will be loaded with white particles. Many pathologists indeed suppose, that a deranged digestion in the stomach is the fundamental part of diabetes. But the fact here mentioned seems to me, in some measure, inconsistent with that theory; for it shows that the food in diabetes undergoes the usual changes in the stomach, and is introduced into the blood in the usual form, so far as sensible characters enable us to judge. We may therefore be allowed to conjecture, that the essential derangement in diabetes is not a derangement of the primary digestion in the stomach, but of the secondary digestion in the blood-vessels, by which the unassimilated nutriment no longer undergoes the same series of changes as in the healthy state.

I conclude with a few remarks upon the physical and chemical characters of this variety of serum.

The colour of the serum is generally a milk-white; sometimes a cream-yellow; or a yellowish-brown, when the liquid bears a striking resemblance to thin oat-meal gruel. There is sometimes little discolouration, the serum merely losing its limpidity, and changing its hue so as to resemble a weak syrup made of coarse sugar.



In all the instances in which I have examined the liquid with the microscope, it showed a great number of solid granules mechanically suspended in it. They are less in size than the corpuscles of the blood, generally of irregular shape ; but often spherical, and having the appearance of a nucleus in the centre, most probably from the refraction of light. These particles were as abundant in the syrup-like serum, as in the more opaque varieties ; but they were less regular in shape, and seemed to be themselves translucent.

It sometimes happens, as has been observed both by Hewson and Hunter, that after the liquid has stood for some time, the white particles separate from it, and rise to the surface like cream. Hewson attempted to effect this separation by churning the serum, but without success. I accidentally hit upon a process by which the object is readily effected. It consists in saturating the liquid with common salt, which so much augments its specific gravity, that the opaque particles becoming relatively lighter, rise to the surface, either immediately, or soon after. This process has the further advantage of preserving the liquid. I still possess some of the original specimens obtained in November, 1840, on which the observations narrated above were made. One of them is the pure serum obtained before the meal. The other three contain white matter, which in two of them is still swimming in the liquid, nearly as when it first separated. In the third, again, the white matter, after swimming at the top for about two years, became denser, and fell to the bottom, where it has since remained. This precipitation was probably owing to the action of the air ; as I have twice known it happen in a single night, when the air was not excluded by filling the phial completely and then firmly corking it. On examining with the microscope the concrete mass, after *creaming*, it is found to consist entirely of amorphous granules. It is obvious, indeed, that the white particles undergo a change in their mode of aggregation by the action of the salt, as they are readily separable by the filter after it but not at all before it.

The white matter separated by the filter is insoluble in water, and is thus easily purified from the salt with which it is mixed on the filtering paper, by steeping the latter in water, and then cautiously drawing off the water holding the salt in solution. Thus obtained it has the form of a fine white powder, which in two specimens in my possession bears a very close resemblance to wheaten flour. On holding a little of it in the flame of a spirit lamp upon a platinum spatula, it was immediately charred, and burned away almost completely. Dr. R. D. Thomson was kind enough to examine a specimen of it for me, but it was too minute in quantity to admit of a satisfactory analysis. He found it quite insoluble in ether and alcohol, while it dissolved in caustic potash. On boiling it in a solution of sugar of lead, it gave traces of black sulphuret. He concluded, therefore, that it contained no fixed oil, and consisted most probably of a *protein compound*, like albumen or fibrin.

A further opportunity was afforded of examining the chemical qualities of this kind of serum in some specimens obtained for illustration, with the prospect of submitting this subject to the consideration of the Society.

A man about thirty years of age, after fasting eighteen hours, dined upon twenty-four oz. of a pudding, consisting of two parts wheaten flour, and one part suet, seasoned with salt. Two oz. of blood taken before the meal, yielded a perfectly limpid serum. Seven ounces were taken three hours after the meal, and the same quantity six hours after it. The serum from the former was like syrup, but a little white: that from the latter was milk-white. The white matter in the latter was separated by Dr. Thomson, by means of salt and the filter, and appeared similar to the substance he had before examined. It contained no fixed oil. The other specimen of serum threw up its cream spontaneously. It left upon the filter only a trace of white matter, but a notable proportion of a fixed oil, which was easily demonstrated, by merely drying the filtering paper, and holding it between the eye and the light. It can scarcely be doubted that this oil was derived from the suet of the pudding, while the white proteinaceous substance most probably represented the gluten of the flour. Thus two of the three elements of which the food consisted, were found in the blood, but the starch, the most abundant of all, was sought for in vain.

*Postscript.* After the meeting of the Society on the evening of the 13th inst., it occurred to me as possible, that the starch might be converted by the organs of digestion into sugar, and be absorbed in that form into the blood. I accordingly procured some yeast next day, and treated with it the serum of the blood, which had been taken three hours after the meal, proceeding in the same way in which I am in the habit of examining diabetic urine. Fermentation ensued, and continued about forty-eight hours, the heat not having been regularly maintained. The serum from the blood of another individual who had used the same diet, but more sparingly, was treated in the same manner, when the same result ensued, only the gas was somewhat more abundant. But what struck me as more remarkable still, was, that the serum of the blood which had been taken from both these individuals after fasting, likewise fermented; although the quantity of gas obtained was much less than in the former instances. I found that the largest quantity of gas obtained in these experiments was about equal to that obtained by means of the same apparatus, from a solution of sugar in water, containing five grains to the ounce. Should farther observations confirm the idea here suggested of the existence of sugar in the blood as a normal product, it is obvious that a corresponding modification must be made of the prevailing theories of diabetes, according to which the production of sugar is regarded, as the essential derangement of action in which that disease consists.





